THE DISTANCES OF SIX PLANETARY NEBULAE

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In a previous note to these Proceedings[1] the parallax was published for the planetary nebula N.G.C. 7662. Attention was called to the scarcity of material then existing for the distances of the nebulae in general. The work has since been taken up with the 60-inch reflector of the Mount Wilson Observatory (the equivalent focal length of 80 feet being used), and in all, the parallaxes of eight nebulae have now been determined; six of these are planetaries, while the other two are spirals; the full details for the latter have been published in *Mount Wilson Contributions*, No. 158.

The images of the central stars were even better adapted to accurate measurement in the case of the five other planetaries measured after N.G.C. 7662 than on the plates of this object; here the nebulous ring was close to the central star and of considerable density; in all others, however, the nebula is either so much fainter than the central star, as in N.G.C. 2392, 6804, 6905, and 7008, that it is hardly visible on the plates, or it is at such a distance from the central star, as in N.G.C. 6720, that the nebula is not likely to interfere with measuring the central images. For this reason the existence of a large systematic error in the parallaxes is very improbable; other conditions also favor the belief that any systematic error will be small. As all the fields are near the Milky Way we have an abundance of comparison stars close to the central stars; in no case was the distance greater than seven minutes of arc; the central stars have in all cases the appearance of normal stars and are measurable with great accuracy.

N.G.C. 2392 is relatively bright; on that account a rotating sector with an opening of 36 degrees was used in order to make the central star comparable in magnitude with the faint stars which are preferably to be used for comparable purposes.

In table 1 the observational material is collected for the fields of all six planetaries.

The central star of N.G.C. 6720 is so faint that exposures of 35 or 40 minutes might have been better; fortunately, for this nebula another reliable parallax determination is available—that by Newkirk, who has derived from 74 plates taken with the Crossley reflector of the Lick Observatory a parallax of $+0''.015 \pm 0''.007$.[2] In the following discussion the weighted mean, viz., $+0''.008$, has been used for the absolute parallax.

To derive a homogeneous system for the photographic magnitudes of the central stars, counts were made of the number of stars of equal and brighter magnitudes in as large an area as the plates would allow; then with the help

of Table IV of *Publications of the Astronomical Laboratory at Groningen*, No. 27, the apparent photographic magnitudes, m, were derived.

The values are given in the third column of table 2; by means of the formula $M = m + 5 + 5 \log \pi$, we can derive the absolute magnitudes M, which are given in the fourth column.

The mean absolute magnitude is +9.1 and the deviations from this mean are small; this may be due to a small dispersion or to the choice of objects; the material, however, is still insufficient to discern which of the two possibilities is the cause.

This faint absolute magnitude, +9.1, is noteworthy because the spectra of these objects consist in many cases mainly of bright lines, whereas, with the stars at large, bright-line spectra are usually associated with high luminosities;

TABLE 1

N. G. C.	EXPOSURE TIME	NUMBER EXPOSURES	NUMBER OF COMP. STARS	π REL.	P. E.
2392	15^m	18	8	+0″.020	±0″.003
6720	25	14	9	+0.002	0.005
6804	25	18	8	+0.020	0.003
6905	20	18	9	+0.013	0.002
7008	20	20	9	+0.014	0.004
7662	25	16	8	+0.021	±0.004

TABLE 2

N. G. C.	π ABS.	m	M
2392	+0″.022	10.0	+ 6.7
6720	+0.008	14.7	+ 9.2
6804	+0.022	13.4	+10.1
6905	+0.015	14.5	+10.4
7008	+0.016	12.8	+ 8.8
7662	+0.023	12.9	+ 9.7

for the Wolf-Rayet stars for instance, whose spectra resemble those of the planetaries in many respects, we find a mean absolute magnitude not far from 0.[3] On the other hand, assuming the relation between luminosity and radial velocity found for the stars to apply to the planetary nebulae, the high radial velocities observed for these objects, about 29 km. per second,[4] are in good agreement with their low intrinsic brightness. Thus, for 13 K and M stars of mean absolute magnitude 10.0, Adams and Strömberg found a mean radial velocity of 30 km. per second.[5]

One class of stars, which seems to take an intermediate position, is that of the novae, whose spectra pass through the planetary spectrum towards that of the Wolf-Rayet stars. The parallax-material, which is extremely scarce as yet and includes only 3 novae, points to absolutely faint magnitudes, in the

mean +6.9, for these stars when at their minimum luster. The radial velocities, however, for the three cases in which they have been determined, are small, in the mean 10 km. per second; this would indicate high luminosities. It should not be forgotten, however, that the relation between luminosity and radial velocity is based on stars of the same spectral type and it is questionable if this relation may safely be applied to stars of all types, including planetaries and novae.

The appearance of the nebulosity around Nova Persei and especially the little nebulous ring, which was photographed by Ritchey[6] and Pease[7] in 1917, opens the way for speculations concerning a possible relation between novae and planetary nebulae. To arrive at conclusions, however, further observational data are necessary.

The size of the planetary nebulae can be deduced from the above mentioned parallaxes, by which the diameters measured in arc can be converted into astronomical units or into light-years; the results are given in table 3; for the diameters in this table the major axes have been used.

TABLE 3

N. G. C.	DIAMETER		
	Angular	In astronomical units	In light-years
2392	46″	2,100	0.03
6720	80	10,000	0.16
6804	32	1,450	0.02
6905	47	3,100	0.05
7008	95	5,900	0.09
7662	31	1,350	0.02

By comparing these values with the size of our solar system (the diameter of the orbit of Neptune is 60 astronomical units) it is clear that the planetary nebulae must be of enormous size.

[1] Maanen, A. van, these PROCEEDINGS, **3**, 1917, (133–136).

[2] Newkirk, B. L., *Lick Obs. Bul., Univ. Cal., Berkeley*, **9**, 1917, (100–107).

[3] Maanen, A. van, *Pub. Astron. Soc. Pacific, San Francisco*, **30**, 1918, (308).

[4] Campbell, W. W., and Moore, J. H., these PROCEEDINGS. **1**, 1915, (496–498).

[5] Ritchey, G. W., *Pub. Astron. Soc. Pac., San Francisco, Cal.*, **29**, 1917, (256).

[6] Adams, W. S., and Strömberg, G., *Mt. Wilson Contr.*, No. 131; *Astroph. J., Chicago*, **45**, 1917, (293–305).

[7] Pease, F. G., *Ibid.*, **29**, 1917, (256–257).